Beyond Pubertal Timing: New Directions for Studying Individual Differences in Development

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Abstract
Dramatic physical and emotional changes mark puberty as one of the most important transitions of the human life span. To date, the majority of psychological studies on puberty have focused on pubertal timing, or when children mature relative to their peers. Yet understanding why puberty is meaningful requires adequate attention to multiple domains of developmental variation. The current article outlines four additional aspects of puberty relevant to health and well-being: tempo, synchrony, secular trends, and perceived development.

Keywords
puberty, timing, tempo

For approximately the past half century, psychological research on puberty has emphasized the importance of pubertal timing, or when children reach specific physical milestones relative to their same-age, same-gender peers. Differences in emotional adjustment between early developers and later-maturing peers are clear: Earlier puberty—particularly in girls—increases vulnerability for problems in adolescence and early adulthood, including depression, anxiety, disordered eating, delinquency, school dropout, and sexual victimization (reviewed in Mendle & Ferrero, 2012; Mendle, Turkheimer, & Emery, 2007). Because physical maturation outpaces cognitive and emotional development, this trajectory is often attributed to early developers' contending with the challenges of puberty with fewer resources than peers who mature at a later chronological age (e.g., Ge & Natsuaki, 2009).

Although the literature on pubertal timing is rich, informative, and well replicated, other individual differences in puberty have not been as rigorously investigated. The present article outlines new directions for puberty research, highlighting four developmentally critical but understudied dimensions of puberty: tempo, synchrony, secular trends, and perceived development. Although this article considers these dimensions primarily as antecedents of health and well-being, it is worth noting that the origins of these four dimensions also merit consideration—particularly the genetic and environmental influences that help explain why puberty can vary across children, time, and culture.

Pubertal Tempo
Children differ not just in when they mature, but also in how quickly or slowly they develop. This rate of physical maturation is known as pubertal tempo. The typical progression from the early stages of puberty to full physical maturation spans approximately 4 years (Herman-Giddens et al., 2012; Susman et al., 2010). Yet individual variations in pubertal tempo can be striking, with extremes ranging from 1 year to 7 or more years. According to the maturation compression hypothesis, rapid pubertal tempo will demand a comparably quick adaptation to new biological and social milestones, whereas a more gradual progression might be less noticed or attended to, both by a developing child as well as by family or acquaintances (Mendle, Harden, Brooks-Gunn, & Graber, 2010, 2012). Rapid tempo might also reflect hormonal differences with important implications for mood and behavior, given that a quicker pubertal progression has been associated with...
higher levels of circulating estrogen and follicle-stimulating hormone in girls (de Ridder et al., 1992).

Four studies to date have explored associations between pubertal tempo and psychosocial outcomes. Initial investigations suggested that rapid pubertal tempo was the strongest predictor of depression for boys, whereas early pubertal timing was the strongest predictor for girls (Mendle et al., 2010). Rapid pubertal tempo in boys has also been related to social difficulties (Mendle et al., 2012) and substance use and experimentation (Castellanos-Ryan, Parent, Vitaro, Tremblay, & Séguin, 2013). Marceau, Ram, Houts, Grimm, and Susman (2011) reported a somewhat different pattern of results, in which rapid pubertal tempo consistently predicted measures of girls’ psychological problems but was less consistently associated with outcomes for boys. Lastly, pubertal tempo has been investigated as an outcome variable, with low levels of parental warmth early in childhood predicting faster tempo among children with high physiological reactivity to stress (Ellis, Shirtcliff, Boyce, Deardorff, & Essex, 2011).

Although findings on pubertal tempo are still emerging, the current research suggests two conclusions. First, quicker tempo appears to be more strongly associated with problem outcomes than slower tempo. This is perhaps not surprising, given that rapid change—regardless of at what point in the life span it occurs—is often more difficult than gradual change (e.g., Brown & Harris, 1978). Second, pubertal tempo accounts for additional, unique variation in psychological problems above and beyond the effects of timing. As future studies explore pubertal tempo, questions to resolve include how the effects of pubertal tempo may vary across gender and how pubertal timing and tempo intersect. Does rapid tempo later in adolescence have the same impact as rapid tempo early in adolescence?

### Pubertal Synchrony

Marshall and Tanner’s (1969, 1970) foundational research on puberty established two sets of standards for the field. First, they documented qualities and characteristics of the normal progression of puberty. Second, they identified how this process may vary across children. In addition to timing and tempo, they described individual differences in synchrony, or variation between different pubertal indicators. Puberty includes numerous different bodily changes: breast development and menstruation in girls; voice changes in boys; increase in height, weight, and muscle mass; and sebaceous skin changes. Pubertal synchrony can be thought of as the temporal relationships between when these individual characteristics develop.

Discussion of pubertal synchrony within the research literature has been surprisingly rare. This may, in part, be due to limited data on growth spurts (which Marshall and Tanner emphasized) in many studies. More recent work has explored the synchrony simply between two indicators of puberty—namely, breast and pubic hair development in girls and testicular and pubic hair development in boys (Novotny, Daida, Morimoto, Shepherd, & Maskarinec, 2011; Susman et al., 2010). A high degree of synchrony indicates that the level of development in one area of puberty “matches” the level of development in another area.

Synchrony has been investigated with regard to medical outcomes, such as bone density and obesity risk (e.g., Biro et al., 2003; Yilmaz et al., 2005). But just as differences in timing and tempo predict emotional adjustment, differences in synchrony might also play a role in psychological well-being. Both individual and social responses to maturation might differ to the extent that various bodily changes occur in conjunction with each other. Consider, for example, the contrast between a tall, muscular boy with a high-pitched, cracking voice and a shorter, slighter boy whose timbre matches his appearance. Greater synchrony might contribute to a sense of being fully immersed in the pubertal transition, whereas a comparatively less coordinated maturation might suggest that puberty is a sporadic or unpredictable process. Alternatively, greater synchrony might have an amplifying effect, because concurrent changes may seem more intense and pervasive than asynchronous ones. Although direct investigations of synchrony and psychological outcomes have not yet been conducted, investigations of related questions seem to favor this second explanation. For example, Smolak, Levine, and Gralen (1993) observed that the coincidence of a girl’s first menstrual cycle (known as menarche) with significant maturational events, such as school transitions or first dates, was associated with poorer psychological outcomes than uncoordinated biological and social changes.

### Secular Changes in Puberty

Both girls and boys seem to be entering puberty at increasingly younger ages. In the middle of the twentieth century, average age of onset of breast development (or thelarche) was 11.15 years (Marshall & Tanner, 1969). By the 1990s, the average age at thelarche was 9.96 years for European Americans and 8.87 years for African Americans (Herman-Giddens et al., 1997); a decade later, twice as many girls displayed visible signs of breast development at ages 7 and 8 years (Biro et al., 2010). Likewise, boys currently exhibit initial signs of development approximately 1.5 years earlier than they did in the mid-twentieth century (Herman-Giddens et al., 2012; Marshall & Tanner, 1970). Although the origins of this trend remain uncertain (and likely attributable to multiple factors), common explanations include exposure to endocrine-disrupting
chemicals, such as those often found in plastics, flame retardants, and pesticides, as well as changes in diet, nutrition, and rates of obesity (Lee & Styne, 2013).

Parents, scientists, and the mainstream media have all voiced persistent concern about earlier pubertal onset. Yet there has been far less interest in when puberty ends. In girls, one indicator of the later stages of puberty is menarche. Interestingly, average age at menarche in both Europe and the United States has declined far less dramatically than other pubertal characteristics, resulting in longer intervals between the start of puberty and menarche (Aksøgaard, Sørensen, Petersen, Skakkebæk, & Juul, 2009; Biro et al., 2006; Herman-Giddens et al., 1997; Lee & Styne, 2013). Similarly, although boys start puberty on average 1.5 years earlier than 40 years ago, they seem to complete the process approximately 6 months later (Herman-Giddens et al., 2012; Marshall & Tanner, 1970). In other words, although research in this area is still evolving, children today seem to be spending a greater portion of their life in puberty than children in the past.

What does it mean to have an entire generation navigating puberty at progressively younger ages and for progressively longer periods of the life span? First, dominant psychological theories of puberty are based on studies which are now several decades old, and the meaning and consequences of puberty for today's children have likely changed. Findings from the literature on boys' pubertal timing support this: While earlier maturation was historically considered advantageous for boys (Mussen & Jones, 1957, 1958), more recent research suggests that early puberty holds many of the same drawbacks for boys as for girls (reviewed in Mendle & Ferrero, 2012). Second, secular declines in the timing of pubertal onset have ironically coincided with later ages of social maturity, including the new developmental stage of “emerging adulthood.” This lengthened gap between biological and social maturation may present both individual and societal costs. Not only do children contend with puberty at younger ages, but disparities between social and biological maturity are believed to facilitate risk-taking behaviors that contribute to adolescent delinquency, mortality, and injury (e.g., Moffitt, 1993). In fact, in Goldstein’s (2011) innovative historical analysis, patterns of adolescent mortality over a 250-year span almost perfectly paralleled secular declines in puberty. Thus, secular declines may mean puberty is generally a more vulnerable time for today's children and may additionally moderate individual differences such that timing, tempo, or synchrony matter in a different way now that the overall transition is lengthier.

Self-Perceptions of Development

The growing awareness of secular trends in puberty has accompanied increased interest in how puberty is measured. Although there are a variety of ways to assess development, one of the most recommended techniques is a physical exam (Dorn & Biro, 2011). Such exams are extensive and intimate, and they correlate inconsistently with children's self-reports of their own development: Although children in some studies have been able to describe their puberty with relative accuracy (Stephen, Bryant, & Wilson, 2008), other studies have indicated weak agreement between children's reports of maturation and the level of maturation assessed by a trained examiner (e.g., Wu, Schreiber, Klementowicz, Biro, & Wright, 2001).

In general, different ways of measuring puberty, even if they vary in validity and accuracy, are assumed to represent the same underlying process. Because of potential inaccuracies, children's self-reports of maturation have been considered an imperfect record of this process (Dorn & Biro, 2011). Yet self-perceptions may be among the most psychologically revealing aspects of development, as they will reflect qualities of the individual (i.e., mood, personality, cognitive style, and personal history) in addition to objective aspects of maturation (Moore, Harden, & Mendle, 2014). After all, children are not trained medical professionals, and their self-reports represent their own truths. Physical exam guidelines, for example, recommend palpation to differentiate breast tissue from adipose tissue, which may otherwise be confused. Yet if a girl visibly appears to have breasts—to herself, to her peers, and to any other person she may encounter, and only a trained examiner can determine otherwise—her life experiences will be commensurate with the more obvious interpretation of her physical appearance.

Emerging research confirms that perceptions of maturation are likely independent, to a degree, from actual pubertal status. In studies that include multiple measurements of puberty, perceived pubertal timing is more strongly associated with outcomes such as substance use, depression, anxiety, and sexual risk taking than more reliably reported indicators of timing, including age at menarche (Conley & Rudolph, 2009; Graber, Lewinsohn, Seeley, & Brooks-Gunn, 1997; Graber, Seeley, Brooks-Gunn, & Lewinsohn, 2004; Moore, Harden, & Mendle, 2014; although no studies have directly contrasted self-perceptions with physical exams when predicting psychological outcomes). Interestingly, perceptions of puberty are comparatively stable. Although children's bodies and social worlds may change and evolve throughout puberty and adolescence, children's perceptions of development remain relatively constant (Cance, Ennett, Morgan-Lopez, & Foshee, 2012), which supports the idea that perceived puberty is at least partially shaped by trait levels of affect, cognition, and personality. Therefore, rather than considering children's self-reports an inadequate proxy for a physical exam, researchers should accept the potential for...
research that purposefully distinguishes between perceived and biological maturation to help resolve longstanding mechanistic questions. Only actual maturation will be affiliated with neuroendocrine changes, whereas perceptions of maturity—regardless of their accuracy—might lead children to seek out experiences or environments consistent with their assumptions, or to behave differently in their relationships with parents or peers.

Conclusion

Capturing variation in puberty—and understanding its relevance to health and well-being—is by no means a simple task. Although the domains of tempo, synchrony, secular change, and perceived development are described separately here, two points should be noted. First, these domains are, to some degree, intertwined—particularly in data collected at a single time point. Returning to the example of the tall boy with an unchanged voice, low synchrony at a single time point could also imply a slow tempo. Likewise, secular trends might reflect changes in timing (as indexed by average age of onset of development), slower tempo (as indexed by the prolonged duration between thelarche and menarche), synchrony (because menarche is not tightly linked with other secondary sexual characteristics), or a combination of all three. Second, discriminating among these domains will be particularly challenging during the core puberty years. To capture all sources of variation accurately, data must be collected at comparatively frequent intervals over a dauntingly long span of time—from before the first signals of puberty until all participants have reached full physical maturation.

How, then, can we move beyond pubertal timing in a world of research realities and imperfect data? One solution comes from quantitative researchers, who are increasingly developing strategies that allow for the effective combination of multiple data sets. Integrative data analysis (IDA), for example, aggregates raw, individual-level data from separate studies in a simultaneous analysis of a pooled data set (Curran & Hussong, 2009). Assuming that certain measurement qualities align, IDA would allow researchers with data on children from different age ranges to combine resources and capture the entire range of development. This would not only permit more accurate and interesting analyses than would be possible using a single data set but would increase statistical power and base rates for low-frequency behaviors and symptoms. It would also allow for the combination of data from multiple time periods, enabling a richer exploration of secular changes. A second possibility for moving forward is more prosaic: Greater awareness of and attention to other sources of pubertal variability may help change how studies are conceptualized, conducted, and interpreted. To understand the discrepancies of puberty accurately, we must first recognize that timing is only part of the picture.

Recommended Reading


Declaration of Conflicting Interests

The author declared no conflicts of interest with respect to the authorship or the publication of this article.

References


