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## **Puberty**

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This entry focuses on puberty from a developmental and biopsychosocial perspective. As an integral part of this perspective, physical changes and the mechanisms that trigger the onset of puberty are described, along with the accompanying psychosocial processes. Furthermore, because of interindividual variations in the timing of physical changes during puberty, a review is established on the biological, psychological, and social factors that predict variations in pubertal timing. Conclusions are based on summaries of short- and long-term consequences of pubertal timing on the psychosocial adaptations of the adolescent and suggestions for preventive strategies. Finally, the entry addresses crucial suggestive questions for future research in the area of pubertal development.

Puberty is characterized by the restructuring of biological and physiological functions associated with physical and sexual maturation. The pubertal period is a major developmental milestone of adolescence and a key developmental challenge for the developing individual. Puberty is the most rapid and extensive physical change during postnatal life in humans. Hormonal changes have effects on mood, body, cognition, and personality. Moreover, young people have to face others' reactions to their more mature appearances. Girls and boys have to cope with feelings of sexual arousal and issues of sexual relationships, as well as adjusting their self-images to their new appearances and feelings.

### **Biological Transformations during Puberty**

During puberty, functional and morphological transformations regarding motor abilities and several organ systems (i.e., central nervous system, blood circuit, respiratory system, and digestive system) are observable in males and females. During puberty, girls experience growth of pubic hair (9–13 yrs.), breast development (9–13 yrs.), and growth of the reproductive system. Moreover, they increase in height (10–14 yrs.), and body proportions change. Between 11 and 15 years of age, girls begin their menarche. Physical pubertal changes in boys occur mainly later than in girls. The transformations encompass the growth of the scrotum (9–14 yrs.), pubic hair (10–15 yrs.), enlargement of the penis (11–16 yrs.), and the development of the reproductive system. Furthermore, during puberty, boys increase in height (12–16 yrs.); their body proportions and body hair changes; and they experience voice change and spermatogenesis. In girls, there are also slightly different sequences of changes observable compared with those given above (Tanner, 1975).

An interplay of physiological, endocrine, and brain-related processes triggers the beginning and course of pubertal development. The physiological processes are primarily focused on hormones of the hypothalamic-pituitary-gonadal (HPG) and hypothalamic-pituitary-adrenal (HPA) axes. The hypothalamic sensitivity toward gonadal sex steroids decreases before the first observable signs of puberty are evident (starting about age 6 to 8). This, in turn, uninhibits the hypothalamic-pituitary axis. The consequent increase in the production of hypothalamic gonadotropin-releasing hormone (GnRH) in the hypothalamus and the increased sensitivity of the pituitary gonadotropic (luteinizing hormone [LH] and follicle-stimulating hormone [FSH]) cells to GnRH lead to increasing LH and FSH production. LH and FSH, in turn, stimulate the maturation of the gonads and the production of gonadal sex steroids (mainly estrogens and testosterone) until a balance between pituitary and gonadal hormones is accomplished. Gonadal hormones result in breast development in girls and testicular

development in boys. The hormones of the pituitary gland influence body cells, resulting in changes in body proportion and the function of organ systems, for example.

The heightened activity of the pituitary gland also results in an increase in androgen production in the adrenal gland. Adrenergic androgens trigger physical maturation, such as growth of pubic/axillary hair and acceleration of bone and muscle growth. Again, feedback loops control the production of puberty-related hormones via the involved brain structures (Fechner, 2003).

### **Effects of Biological Changes**

New insights about the effects of hormonal changes during puberty on psychological functioning and interpersonal behaviors (e.g., depressive affect, sexual activities, or aggressive behaviors) were gained during the past years. In general, the direct effects were rather weak, and instead, mediators were identified. For example, an increase in testosterone predicted externalizing behavioral problems mediated by social integration in deviant peer contexts. Furthermore, behavioral problems before puberty contributed to adolescent externalizing problems during puberty. Thus, a complex interplay of biopsychosocial variables before and during puberty seems to link the relationship between hormones and behaviors (Susman, 1997). It has also been suggested that the brain-related transformations that are typical for puberty might have a stronger relationship to behavioral expressions of adolescents than do hormone-related changes. The limbic system (especially the amygdala) and related hormonal systems undergo transformations that are linked with hyperresponsiveness toward environmental stressors, more negative affect, higher variability in mood states, and increasing consumption of alcohol and psychoactive drugs. As, until now, these assumptions have been based primarily on experiments with animals, validation on human data is still needed (Spear, 2000).

Most adolescents cope well with the physical, central nervous system (CNS), and endocrine changes during puberty, and only a small proportion of adolescents struggle with negative body image, emotional problems, or temporary irritations as a result of adaptation stress or the accumulation of changes in different domains (i.e., school, social relationships, biological changes). Girls have more frequent negative feelings during puberty than do boys. This is especially true for cultures with beauty ideals of very thin women. Furthermore, social changes in the family context (i.e., individuation from parents), peer context (i.e., striving for acceptance and integration in peer groups), and growing interest in peers of the opposite sex accompany physical maturation during puberty.

### **Antecedents of Differences in Pubertal Timing**

The timing of physical changes during puberty (i.e., pubertal status relative to a given age) varies tremendously across individuals. For some years, leptin, a protein produced in fat cells, has been seen as the primary metabolic signal that activates the release of gonadal hormones (Friedman & Halaas, 1998). Leptin levels indicate the proportion of fat in the body and modulate energy balance and feelings of hunger. When a certain proportion of body fat (about 17%) is reached, leptin signals readiness for reproduction to the hypothalamus, which, in turn, influences the production of gonadal hormones. Empirical results support a role for leptin in triggering puberty, but other neuronal systems and genetic and psychosocial factors might also interact, because not all overweight children enter puberty at an earlier age (Larmore et al., 2002).

For a long time, genetic differences were seen as the only determinants of pubertal timing. Indeed, menarcheal age of mothers and daughters correlate .26 to .45, and differences in pubertal timing by ethnic groups suggest at least some influence by heredity. However, the most powerful predictor of the timing of pubertal events seems to be socioeconomic status (earlier timing in high-SES contexts), mediated by differences in nutrition and health. The decrease of age at menarche (or at least a greater likelihood that age of onset of the first stages of puberty is declining; Coleman & Coleman, 2002) that has been seen during the last 150 years is also an indicator for environmental effects on the timing of pubertal maturation. Because of the short time span during which age at menarche has declined, genetic influences seem to be rather unlikely.

Moreover, the interplay of psychosocial factors (e.g., nutrition, sports, family conflict, and critical life events) predicts the onset of pubertal changes, especially in girls. Following an evolutionary theory proposed by Belsky, Steinberg, and Draper (1991), contextual factors such as family and economic stress or absence of the father may be linked with early pubertal maturation via depressive feelings and increasing fat accumulation. Hormones related to negative emotions (i.e., cortisol) and amount of body fat (i.e., leptin) might influence the activity of the HPG axis, which modulates the release of gonadal hormones. Following this theory, in later adolescence and adulthood, early maturation should be related to a quantitative rather than qualitative reproduction strategy (i.e., more sexual partners, less investment in offspring). At least for girls, the model is in part empirically validated. An alternative (genetic) model states that fathers' withdrawal from family life, changing sexual relationships, and aggressive behavior (that promotes family conflict) is due to an androgen receptor (AR) localized on the X-chromosome gene. Molecular-genetic research showed that shorter alleles on the AR gene were related to the greatest androgen activity (e.g., testosterone). Androgens, in turn, are associated with aggression, dominance, or antisocial behaviors. The hypothesis of Comings, Muhleman, Johnson, and MacMurray (2002) is that this gene is transmitted to daughters, who then show behavioral problems in childhood, and that it fosters earlier pubertal maturation, changing sexual relationships, and unstable relational patterns. First results show that genetic similarities between father and daughter explain most of the variance of the relationship between father absence and early pubertal maturation in girls. Nevertheless, until now, both the evolutionary and the genetic model were not tested competitively in a longitudinal sample.

### **Consequences of Variations in Pubertal Timing**

Interindividual differences in the timing (and tempo) of pubertal physical development have consequences on concurrent behaviors and long-term adjustment. Different conceptual approaches have been suggested. The first group of approaches specifies the nature between pubertal timing and behaviors. One model states that every deviation from the normative timing (early and late maturation) implies difficulties for psychosocial development (deviance hypothesis). Following another model, adjustment problems occur particularly in adolescents with early pubertal timing because they lack the time to adapt to pubertal changes and associated social consequences (stage termination or early timing hypothesis). As several empirical studies have shown, effects of early or late maturation on psychosocial development differ between adolescents from different ethnic backgrounds. For example, in a multiethnic American

sample, Hayward, Gotlib, Schraedley, and Litt (1999) showed that among Caucasian girls, early menarche was related to higher depression. Contrary to this finding, puberty had no impact on depression in Hispanic or African American girls, which might be due to different cultural stereotypes of body ideals. Moreover, age and gender moderate the validity of the deviance and stage termination hypothesis. For example, in Caucasian American girls, the stage termination hypothesis holds for the explanation of depressive symptoms through adolescence, whereas in boys, it is true only at the beginning of puberty, when biological changes coincide with other changes and stressors (Ge et al., 2003). Contrary to this, in a German sample of similar age, early- and late-maturing girls had more internalizing problems than their age-mates, which supports the deviance hypothesis (Silbereisen & Kracke, 1997). Nevertheless, both models do not specify mediational processes, such as social events.

The second (more recent) group of approaches investigates the nature of the biopsychosocial processes mediating the relationship between pubertal timing and adaptation. The comprehensive conceptual model by Brooks-Gunn, Graber, and Paikoff (1994) postulates three mediational processes between hormonal changes and outcomes during puberty. First, pubertal timing links the effect between hormonal changes and behaviors (e.g., hormonal changes lead to negative affect via changes in body proportions). The second pathway states that social experiences resulting from hormonal changes and (especially visible) changes in secondary sex characteristics explain problem behaviors. Moreover, social experiences themselves can influence hormonal processes during puberty (e.g., excessive sports delay the production of gonadal hormones). Finally, the mediation between hormonal and CNS changes during puberty relate to both externalizing and internalizing problems.

Empirical results on the consequences of pubertal timing have revealed that in girls, early maturation is linked with more mature interpersonal relationships in family and peer context (e.g., older male friends) that temporarily lead to more frequent externalizing problem behaviors (e.g., substance use) due to the peer model. Early-maturing girls show more internalizing problems, such as poor body image, eating problems, or depressive symptoms. This effect is primarily due to the girls' feelings of incongruity with culturally accepted body ideals. Furthermore, as indicated by differences in reaction times and by EEG-measured evoked potentials, early-maturing girls are more sensitive to and alerted by semantic information that concerns sex-related issues than are other girls. In boys, late maturation during puberty is associated with poor body image and self-worth, but early maturation is associated with depressive symptoms, which might be due to rapid hormonal changes and heightened vulnerability toward life stress (Ge, Conger, & Elder, 2001).

Taken together, the short-term consequences of early or late pubertal maturation during the adolescent period are primarily the indirect result of interindividual differences in pubertal timing in early adolescence. Consequences are also evident in the long term, when subjects reach their 30s. Especially in females, early maturation has been seen to lead to precocious involvement in heterosexual contacts during adolescence, which fosters early motherhood and marriage. This, in turn, has been linked with less successful occupational attainment in adulthood. With the exception of alcohol problems, few long-term effects have been found for men with late pubertal timing in males (for a review, see Weichold, Silbereisen, & Schmitt-Rodermund, 2003).

### **Utilization in Prevention Planning**

Concerning the prevention of adaptation problems resulting from biological transformations during puberty, the following aspects seem to be important. First, preadolescents, parents, and teachers should be informed about the normality of biological changes in general (focused on changes of body and fat proportions and on CNS changes that modulate adolescent behaviors) and possible variations of the timing of pubertal events. New foci in sexual education in schools (for instance, associated with a general program to empower youth, e.g., by teaching life skills) or in the media could be possible approaches. Important here is the optimal timing of such preventive strategies so that adolescents with early pubertal timing do not enter puberty unprepared. Furthermore, at the beginning and during puberty, parents and teachers should be aware of temporary yet nevertheless serious adaptation problems of adolescents. It seems advisable to reduce risk factors and promote protective factors that are known to relate to adaptation problems during puberty. For instance, early approaches that target irrational thinking in girls and thus enhance positive feelings about their own bodies can help to prevent depressive feelings during puberty (Haldeman & Baker, 1992).

### **Directions for Future Research**

Further research should, first, concentrate on the empirical validation of the model proposed by Brooks-Gunn et al. (1994), which focuses on the interplay of biological changes, social behaviors, and personality features as predictors for adaptation problems during the pubertal period. Although parts of the model have been proven in earlier research, there is a lack of studies that include measures on CNS aspects of behaviors and emotions. Recent research indicates that age-specific changes in the structure and function of the CNS relate to behaviors typical for early adolescence (i.e., risk-taking behaviors) even more than the hormonal changes (Spear, 2000). Moreover, a bidirectional relationship between the CNS and hormones should be included in the model, because both systems interact (e.g., via motivational states).

A second future research effort should concentrate on the consequences of the fact that the secular acceleration affects the somatic aspects of pubertal changes much more than the intellectual and socioeconomic ones. Therefore, further studies need to answer the question as to whether it is really true that some youthful problems, indeed, are rooted in a mismatch between physical and intellectual maturation.

Third, research on the consequences of differences in pubertal timing has focused mainly on problem behaviors and rarely on normative or positive developmental results. Given the fact that the current trend in psychology fosters the investigation of positive aspects of adaptation, the effects of variations in pubertal timing on normative development (e.g., autonomy development) should become a new research focus.

Finally, there is a lack of conceptualization and validation of a model including antecedents and consequences of pubertal development. Evolutionary-theory-based (e.g., Belsky et al., 1991), genetic (Comings et al., 2002), and endocrinological explanations have to be tested competitively and have to be linked with models on consequences of variations in pubertal timing (Brooks-Gunn et al., 1994). This, in turn, could result in a comprehensive model on concrete developmental pathways that can be tested using longitudinal samples.

- puberty

- maturation
- hormones
- leptin
- menarche
- biological change
- girls

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