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Original article

Early Puberty and Childhood Social and Behavioral Adjustment

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A B S T R A C T

Purpose: Early puberty has been linked to higher rates of mental health problems in adolescence. However, previous studies commencing after the initiation of puberty have been unable to explore whether early puberty is preceded by higher rates of these problems. In a large national study, we aimed to determine whether difficulties in behavior and psychosocial adjustment are evident before as well as during the early pubertal transition.
Methods: The Longitudinal Study of Australian Children recruited a nationally representative cohort of 4,983 children at age 4–5 years in 2004. This analysis includes 3,491 of these children (70.1%) followed up at ages 6–7, 8–9, and 10–11 years, with a completed parent report of stage of pubertal maturation at age 8–9 years. Parents reported behavior difficulties (Strengths and Difficulties Questionnaire) and psychosocial adjustment (Pediatric Quality of Life Inventory) at all four waves from ages 4–5 to 10–11 years.
Results: Both boys and girls who entered puberty early (i.e., by age 8–9 years) also experienced poorer psychosocial adjustment at this age. These psychosocial differences were already evident at ages 4–5 and 6–7 years, and persisted to at least age 10–11 years. Similar patterns were evident for behavior difficulties, but only for boys; early puberty was not related to behavior difficulties in girls.
Conclusions: Children with early puberty have different patterns of behavior and social adjustment from the preschool years through early adolescence. At least in part, the association between early-onset puberty and poor mental health appears to result from processes under way well before the onset of puberty.

IMPLICATIONS AND CONTRIBUTION

In a large national sample, children with earlier-onset puberty had poorer mental health from preschool age (age 4–5 years) through to early adolescence (age 10–11 years). For boys, this was evident in behavior difficulties and poorer psychosocial adjustment; for girls, it was poorer psychosocial adjustment.

Up to one in four adolescents have identifiable mental health problems in community surveys [1,2]. The consequences for mental health later in life are substantial: Around 75% of adult mental disorders have an onset by the age of 24 years [3].

Puberty marks a transition point in mental health, with changes in prevalence rates and sex ratios of mental and behavioral disorders after the pubertal transition [4]. Early puberty has been linked to an increased risk for subsequent mental health and behavioral problems [5,6], particularly in girls [7,8]. The literature for boys appears less clear. Different studies find that early or late onset of puberty, or both, is associated with mental health and behavioral problems [9–11].

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There are several reasons why early puberty may increase vulnerability to adolescent mental health problems. More advanced pubertal stage is associated with greater depressive and anxiety symptoms, as well as increased rates of behavior problems [12,13]. Adolescents with early puberty thus enter this risk phase at an earlier point. Behavior problems may also arise because of a mismatch between the emotional reactions and cognitive capacities of young adolescents [8,14]. Early human studies of "off-time" puberty commonly cite emotional immaturity and differential affiliation with older peers as reasons for the greater emotional and behavioral problems of early maturers [15,16].

Life history theory offers a third explanation. Pubertal timing may be the result of both genetic and environmental factors early in life that lead to different developmental trajectories [17–19]. Whereas pubertal timing may in part be determined by the child's adaptation to earlier influences, such as stressful family environments and lack of parental investment and warmth [17–21], mental health and behavior problems might likewise be associated with these environmental influences [22]. Life course theory may be extended to suggest that early puberty might be an evolutionary response to early-life adversities, and in turn may be linked to a suite of behaviors such as aggression, impulsivity, and emotional lability likely to lead to early reproduction [21,23]. From this perspective, emotional and behavioral problems would be expected to become evident earlier in childhood (before early puberty). This possibility has received limited empirical investigation [13]. Reporting findings from a longitudinal birth cohort, Caspi and Moffitt [24] described greater childhood behavior problems among girls who were predisposed to early menarche. However, behavioral problems were not assessed until the age of 9 years, by which time the pubertal process is almost certainly already under way in the early-onset group [25]. Similarly, longitudinal studies describing an increased risk of internalizing symptoms and disorders, and psychosocial symptoms among girls experiencing early puberty [7,26] and disruptive behavior and substance use disorders in boys [7] have not addressed the associations that may already be evident in the prepubertal period.

There is therefore an important gap in the literature regarding whether differences in children's mental health may be seen before the onset of early puberty [7,26]. Our understanding of children's healthy mental development as they transition to adolescence would be better informed by studying the association between social and behavioral adjustment and early puberty across a time frame that includes early childhood. In this study, we investigated whether children who experience early puberty differ in their social and behavioral adjustment in earlier childhood as well as during the pubertal transition, and examined how these patterns differ for girls and boys.

Using prospective longitudinal data from a nationally representative, Australian population-based sample, we examined the extent to which children for whom there was evidence of puberty onset at age 8–9 years differ on measures of social and behavioral adjustment across a range of ages from early childhood, age 4–5 years, up to age 10–11 years. The study examined girls and boys and (1) compared concurrent behavior difficulties and psychosocial adjustment between children who experience early-onset puberty by age 8–9 years and those with later onset; (2) examined data collected from ages 4–11 years, to determine whether differences precede and/or continue beyond early puberty at age 8–9 years; and (3) examined whether differences remain after accounting for other characteristics of the child that may be associated both with puberty and mental health: ethnicity [2,27], body mass index (BMI) [28,29], and family socioeconomic situation [2,27].

Methods

Study design and participants

Participants were from the Longitudinal Study of Australian Children (LSAC). The study design and methodology are detailed further in the study publication [30]. We sampled children aged 4–5 years from the near-universal Medicare (national health insurance) database in 2004, following a two-stage clustered design with approximately 10% of Australian postal codes as the primary sampling unit, stratified by state and by urban versus rural locations. The Australian Institute of Family Studies Ethics Committee approved the study.

The initial participation rate was 59%, recruiting a cohort of 4,983 children. We conducted baseline and follow-up interviews at ages 6–7, 8–9, and 10–11 years at the child's home with the child's primary care giver, who was usually a parent (and to whom we refer as parents throughout this article). At each wave, the interview included a computer-assisted interview schedule with the parent, direct assessments of the children made by the interviewer, and a leave-behind questionnaire to be completed and returned by the parent. Of the original cohort, 3,938 children were maintained in the cohort across all waves (79%). We applied survey weights taking into account differential nonresponse and sample attrition to ensure that the study continued to be representative of the Australian population of children as in the original survey design.

The analytical sample included 3,491 children, 50.8% boys and 49.2% girls (70.1% of the original cohort), who had participated in all of the waves and whose parents gave information on puberty at age 8–9 years. Parents reported children's ethnicity as Aboriginal or Torres Strait Islander for 3.0% of the children, to whom we refer together as Indigenous Australians. Compared with the broader cohort maintained to age 10–11 years, the analytical sample was more advantaged with regard to indicators of socioeconomic status. Among those who did versus did not report puberty data, 50.4% versus 42.1% of mothers had completed high school, 10.6% versus 17.5% of families had no parent currently employed, 15.3% versus 27.8% spoke a language other than English at home, and 6.2% versus 11.7% of mothers were 21 years of age or younger at the time of the child's birth.

Measures

Early onset of puberty. We assessed early onset of puberty at age 8–9 years by adapting items from the Pubertal Development Scale for parental report [31]. Recognizing that the pubertal transition is a complex process with a long genesis, we made the inference that children with parent-reported physical signs of puberty were experiencing an early onset of puberty. The four external puberty indicators were breast growth (girls only), skin changes, adult-type body odor, and body hair. For each, the parent rated their child's development as "has not started yet," "has barely started," "has definitely started," or "seems complete" (Table 1). Girls were grouped as "definitely started" (16.1%) if parents rated any indicator as "definitely started" or "seems complete"; "barely started" (24.6%) if any were rated as

Table 1
Frequency of indicators of early onset of puberty at age 8–9 years

Puberty indication at age 8–9 years	Girls					Boys			
	Skin changes	Adult-type body odor	Body hair	Breast growth	Any indication	Skin changes	Adult-type body odor	Body hair	Any indication
None	81.4	83.3	90.9	77.1	59.3	89.1	88.0	96.3	79.4
Barely	13.2	8.5	5.3	16.2	24.6	8.1	8.3	2.8	14.3
Definite/seems complete	5.4	8.2	3.8	6.7	16.1	2.8	3.7	.9	6.3

"barely started" plus there was no other definite indication; or "not started" (59.3%). Boys were similarly grouped on the basis of skin changes, body hair, or adult-type body odor, with 6.3%, 14.3%, and 79.4% in the "definitely," "barely," and "not" started categories, respectively. Early onset of puberty was more frequent among children from more disadvantaged families, children with a higher BMI, and Indigenous Australian children (data not shown; available on request).

Behavior difficulties. We measured behavior difficulties using the parent-reported Strengths and Difficulties Questionnaire (SDQ). The SDQ is a brief mental health screener for children aged 3–16 years that includes 20 items assessing difficulties in behavior, emotions, and relationships: for example *"restless, overactive, cannot stay still for long; often loses temper; rather solitary, prefers to play alone; many worries, often seems worried"* [32]. The LSAC cohorts use the Australian version age 4–16 years questionnaire at ages 6–7 to 10–11 years, and the United Kingdom version age 3–4 years questionnaire at age 4–5 years (http://www.sdqinfo.org/). The total difficulties score (Cronbach $\alpha = .79–.84$ across the waves), for which higher scores represent worse behavior difficulties, was derived for 99.6%, 96.8%, 99.7%, and 99.0% of children at ages 4–5 to 10–11 years, respectively. Similarly, we derived subscale scores for conduct difficulties ($\alpha = .61–.70$), emotional difficulties ($\alpha = .57–.70$), inattention/hyperactivity ($\alpha = .74–.78$), and difficulties with peers ($\alpha = .49–.65$).

Psychosocial adjustment. We measured psychosocial adjustment using the parent-reported Pediatric Quality of Life (PedsQL) inventory [33]. The PedsQL inventory is designed to assess the health-related quality of life of 2- to 16-year-olds and includes 15 items assessing psychosocial adjustment: for example, problems with *"feeling afraid or scared; playing with other children; doing the same preschool/school activities as children other children his or her age."* The psychosocial health summary score ($\alpha = .82–.87$), for which lower scores represent worse psychosocial adjustment, was derived for 89.1%, 82.1%, 99.8%, and 99.0% of children at ages 4–5 to 10–11 years, respectively, with lower completion at the first two waves because the measure was in a leave-behind questionnaire. Similarly, we derived subscale scores for emotional functioning ($\alpha = .71–.80$), social functioning ($\alpha = .76–.80$), and school functioning ($\alpha = .56–.74$).

Covariates

Socioeconomic status was provided with the LSAC dataset as a composite variable based on parental income, education, and occupational prestige [34], and grouped in quintiles for this analysis. On the basis of directly measured height and weight at each interview, we classified children as underweight, normal weight, overweight, or obese, using international definitions for classifying BMI (kg/m^2) [35,36].

Statistical analysis

We examined mean *z*-scores (measures standardized to mean 0, standard deviation 1) for the SDQ total difficulties measure, Peds QL psychosocial health summary, and each of the subscales at each of the ages, in relation to early onset of puberty at age 8–9 years. We assessed trends in scores according to whether puberty was "not," "barely," or "definitely" started, using linear regression. The first series of models controlled for the child's age in months at the time of assessment. Each of the child and family characteristics (child's ethnicity, family socioeconomic status, and child's BMI) was added to the models to investigate whether controlling for these covariates affected the observed associations. We examined girls and boys separately to explore gender-specific patterns and used gender interaction tests to assess the strength of evidence supporting differential trends among girls and boys. We took the complex survey design into account using first-order Taylor linearization to estimate the standard errors on which we based the 95% confidence intervals, and used weights to account for the complex study design, nonresponse, and sample attrition. We carried out analyses using the survey commands in Stata version 11 (StataCorp LP, College Station, TX).

Results

Bivariate correlations

The SDQ total difficulties scores were strongly related across childhood, with correlation coefficients ranging from .54 between the measures at 4–5 and 10–11 years of age, to .76 between those at 8–9 and 10–11 years of age. Correlations between Peds QL psychosocial health summary scores ranged from .42 between the measures at 4–5 and 10–11 years of age, to .60 between those at 8–9 and 10–11 years of age. Furthermore, correlations reflected association between higher behavior difficulties and poorer psychosocial adjustment at each measurement point; for example, the correlation between SDQ total difficulties and Peds QL psychosocial health summary scores at age 10–11 years of age was −.68.

Regression analysis

The relationships between puberty onset at age 8–9 years and behavior difficulties, and psychosocial adjustment from ages 4–5 to 10–11 years are displayed in Table 2 and Figure 1. Among girls, there was little difference in SDQ total difficulties scores across childhood according to puberty onset at age 8–9 years. In contrast, boys who experienced early puberty had higher SDQ total difficulties scores at age 8–9 years, as well as earlier in childhood at ages 4–5 and 6–7 years, and these differences were subsequently maintained to ages 10–11 years. Gender interaction tests gave some support for a differential relationship between behavior difficulties and early

Table 2
Behavior difficulties and psychosocial adjustment across childhood in children with early puberty at age 8–9 years, compared with those with later onset

	Pubertal onset 8–9 years	Age 4–5 years			Age 6–7 years			Age 8–9 years			Age 10–11 years		
		β[a]	95% CI	p[b]	β[a]	95% CI	p[b]	β[a]	95% CI	p[b]	β[a]	95% CI	p[b]
Total difficulties score													
Girls	Barely	.02	(−.09, .13)	.66	.00	(−.11, .12)	.55	.02	(−.09, .13)	.27	.05	(−.07, .17)	.44
	Definite	.03	(−.12, .17)		.05	(−.09, .19)		.08	(−.05, .21)		.05	(−.11, .20)	
Boys	Barely	.02	(−.12, .16)	.03	.05	(−.09, .18)	.01	.17	(.01, .33)	.002	.07	(−.08, .21)	.03
	Definite	.32	(.05, .59)		.33	(.09, .56)		.32	(.06, .57)		.27	(.01, .52)	
Gender interaction	p[c]	.10			.07			.04			.14		
Psychosocial summary													
Girls	Barely	−.06	(−.19, .06)	.02	−.16	(−.29, −.02)	.01	−.09	(−.21, .02)	.001	−.12	(−.23, .00)	.007
	Definite	−.20	(−.36, −.03)		−.16	(−.31, −.02)		−.24	(−.38, −.10)		−.19	(−.35, −.04)	
Boys	Barely	−.05	(−.20, .11)	.02	−.12	(−.29, .05)	.08	−.22	(−.36, −.07)	<.001	−.21	(−.35, −.06)	.02
	Definite	−.34	(−.58, −.09)		−.16	(−.39, .07)		−.41	(−.65, −.16)		−.14	(−.37, .09)	
Gender interaction	p[c]	.53			.96			.15			.88		

CI = confidence interval.
[a] Regression coefficient reflecting difference in *z*-score, adjusted for age, in each case compared with no indication of puberty onset as the reference category.
[b] Test for trend by indication of puberty onset.
[c] Test for interaction between gender and trend by indication of puberty onset.

puberty in boys compared with girls across childhood, most strongly at age 8–9 years ($p = .04$). Both girls and boys who experienced early puberty had poorer Peds QL psychosocial health summary scores consistently across childhood (Table 2, Figure 1).

Adjusted models

The associations between early puberty onset and behavior difficulties were not substantially attenuated by including socioeconomic status and child's BMI and ethnicity in the models as potential confounding factors (Table 3). Including these factors resulted in greater attenuation of the associations between early puberty onset and psychosocial adjustment (Table 4). The most substantially changed estimates were for girls at age 8–9 and 10–11 years; this attenuation was mainly explained by accounting for BMI, reflecting known associations between BMI, early puberty onset, and psychosocial adjustment. However, these covariates only partially explained the relationship

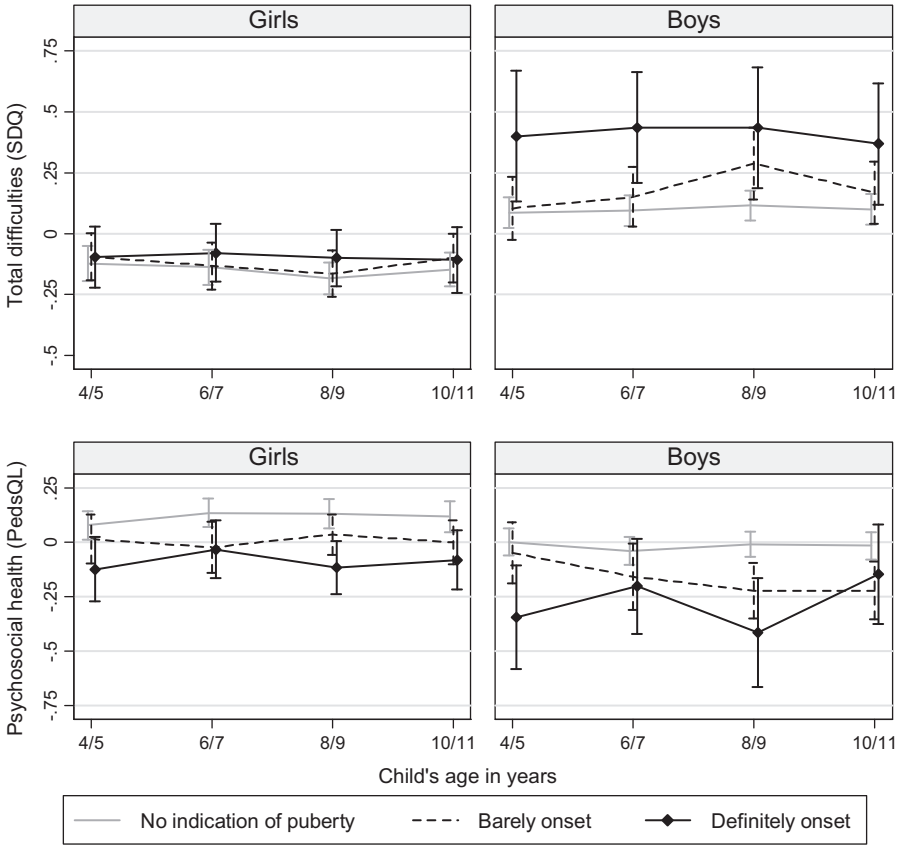

Figure 1. Behavior difficulties and psychosocial adjustment from early childhood to early adolescence in boys and girls with an early onset of puberty at 8–9 years. SDQ and PedsQL presented as mean standardized z-scores with 95% confidence intervals.

Table 3
Behavior difficulties across childhood comparing children with early onset of puberty at age 8–9 years and those with later onset (adjusted for child and family characteristics)

	Pubertal onset 8–9 years	Age 4–5 years			Age 6–7 years			Age 8–9 years			Age 10–11 years		
		β[a]	95% CI	p[b]	β[a]	95% CI	p[b]	β[a]	95% CI	p[b]	β[a]	95% CI	p[b]
Girls													
Total difficulties score	Barely	.00	(−.11, .11)	.62	−.01	(−.12, .11)	.90	−.04	(−.15, .07)	.67	.00	(−.12, .11)	.54
	Definite	−.04	(−.18, .10)		.01	(−.12, .15)		−.02	(−.15, .12)		−.05	(−.19, .09)	
Conduct difficulties	Barely	−.03	(−.15, .08)	.09	−.05	(−.17, .07)	.39	−.07	(−.19, .05)	.02	.01	(−.12, .14)	.31
	Definite	−.14	(−.29, .01)		−.05	(−.20, .09)		−.15	(−.28, −.02)		−.10	(−.25, .05)	
Emotional difficulties	Barely	.02	(−.11, .15)	.97	.10	(−.03, .22)	.16	.03	(−.09, .16)	.31	.09	(−.04, .21)	.53
	Definite	−.01	(−.15, .13)		.07	(−.07, .20)		.08	(−.08, .23)		.02	(−.13, .17)	
Inattention/ hyperactive	Barely	.03	(−.09, .14)	.67	−.06	(−.17, .05)	.98	−.10	(−.20, .01)	.24	−.05	(−.16, .06)	.33
	Definite	.02	(−.11, .16)		.02	(−.12, .17)		−.05	(−.20, .09)		−.06	(−.20, .08)	
Difficulties with peers	Barely	−.02	(−.13, .10)	.89	−.01	(−.12, .11)	.91	.03	(−.08, .14)	.22	−.06	(−.16, .05)	.60
	Definite	.02	(−.12, .15)		−.01	(−.14, .13)		.08	(−.05, .22)		−.02	(−.15, .12)	
Boys													
Total difficulties score	Barely	.00	(−.14, .14)	.05	.05	(−.09, .18)	.02	.16	(.01, .32)	.002	.03	(−.11, .18)	.06
	Definite	.28	(.04, .53)		.29	(.07, .52)		.31	(.06, .55)		.23	(.01, .46)	
Conduct difficulties	Barely	.00	(−.14, .15)	.37	−.09	(−.24, .05)	.20	.09	(−.07, .26)	.11	−.01	(−.17, .14)	.04
	Definite	.11	(−.08, .30)		.27	(.06, .48)		.17	(−.10, .44)		.31	(.09, .54)	
Emotional difficulties	Barely	−.03	(−.15, .10)	.07	.15	(.01, .30)	.001	.21	(.07, .35)	<.001	.03	(−.12, .17)	.21
	Definite	.31	(.03, .58)		.27	(.08, .46)		.45	(.22, .68)		.16	(−.08, .40)	
Inattention/hyperactive	Barely	−.01	(−.14, .13)	.14	.03	(−.11, .18)	.21	.11	(−.03, .24)	.04	.00	(−.13, .13)	.42
	Definite	.21	(−.02, .43)		.16	(−.09, .41)		.20	(−.05, .46)		.10	(−.11, .32)	
Difficulties with peers	Barely	.04	(−.10, .19)	.13	.03	(−.12, .17)	.19	.07	(−.08, .22)	.28	.09	(−.06, .24)	.07
	Definite	.18	(−.06, .41)		.17	(−.06, .39)		.07	(−.13, .28)		.16	(−.07, .39)	
Gender interaction													
Total difficulties score	p[c]	.07			.03			.01			.08		
Conduct difficulties	p	.11			.12			.04			.09		
Emotional difficulties	p	.16			.03			.004			.58		
Inattention/hyperactive	p	.26			.21			.02			.26		
Difficulties with peers	p	.35			.19			.87			.04		

CI = confidence interval.
[a] Regression coefficient reflecting difference in *z*-score adjusted for age, ethnicity, socioeconomic status, and body mass index, in each case compared with no indication of puberty onset as the reference category.
[b] Test for trend by indication of puberty onset.
[c] Test for interaction between gender and trend by indication of puberty onset.

between early puberty onset and poorer psychosocial adjustment.

Table 3 lists the subscales of the SDQ measure and demonstrates that emotional difficulties were most clearly associated with early onset of puberty for the boys, with consistent (but less significant) effects seen for the other SDQ subscales. In Table 4, the clearest effects relating to the psychosocial adjustment measures were likewise for poorer emotional functioning among both boys and girls with early onset of puberty, with consistent (but less significant) effects seen for the other Peds QL subscales.

Discussion

Children experiencing early puberty had greater adjustment problems than their peers, and some of these differences were already evident in the preschool years. Boys for whom the onset of puberty was evident at age 8–9 years had greater behavioral difficulties and poorer psychosocial adjustment from early childhood through early adolescence. However, in girls for whom early onset puberty was evident, only differences in psychosocial adjustment, but not behavioral difficulties, were experienced over the period of early childhood to early adolescence.

The data that had been collected from early childhood in LSAC provided us with the opportunity to examine early indications of puberty onset at age 8–9 years, as well as to prospectively consider mental health from age 4–5 years, well before the onset of puberty. The study also provided us with an opportunity to address associations with early puberty in boys as well as girls, when the latter have usually been the focus of attention [17,18]. The study supports a life course hypothesis that differences in pubertal timing and childhood adjustment may at least in part result from genetic and environmental factors early in life [17–19,23]. The current data suggest that such mechanisms may also operate in males as well as females, and may indeed have stronger and wider-reaching effects in males, evidenced as difficulties in both behavior and psychosocial adjustment.

We controlled for a range of potential confounders in the analyses. Of these, childhood BMI provided only a partial explanation for the association between puberty onset and psychosocial adjustment for girls. Further factors that could be considered in future work include whether prematurity and patterns of prenatal growth offer explanations for the developmental process from early childhood behavioral adjustment to early puberty and later mental health problems [37]. Very early onset of the pubertal process itself is unlikely to explain these findings, because pubertal hormones are rarely elevated before 5 years of age, even in those clinically presenting with premature adrenarche [38]. Nonetheless, a role of very early endocrine mechanisms cannot be completely excluded, because animal models suggest that testosterone and estrogens might interact with stress-regulation mechanisms from as early as infancy in some way that influences attachment and behavior [21]. Indeed a number of factors, including intrauterine development, early childhood nutrition and weight gain, family functioning, and

Table 4
Psychosocial adjustment across childhood comparing children with early onset of puberty at age 8–9 years and those with later onset (adjusted for child and family characteristics)

	Pubertal onset 8–9 years	Age 4–5 years			Age 6–7 years			Age 8–9 years			Age 10–11 years		
		β[a]	95% CI	p[b]	β[a]	95% CI	p[b]	β[a]	95% CI	p[b]	β[a]	95% CI	p[b]
Girls													
Psychosocial summary	Barely	−.06	(−.19, .06)	.02	−.14	(−.28, −.01)	.02	−.05	(−.17, .07)	.03	−.07	(−.19, .05)	.10
	Definite	−.19	(−.35, −.03)		−.13	(−.28, .01)		−.17	(−.32, −.02)		−.11	(−.26, .04)	
Emotional functioning	Barely	−.11	(−.25, .03)	.07	−.12	(−.25, .01)	.003	−.06	(−.17, .05)	.02	−.07	(−.20, .06)	.04
	Definite	−.13	(−.29, .03)		−.21	(−.36, −.06)		−.19	(−.35, −.03)		−.16	(−.32, .00)	
Social functioning	Barely	.01	(−.10, .13)	.18	−.20	(−.34, −.06)	.08	−.05	(−.17, .08)	.07	−.09	(−.20, .02)	.28
	Definite	−.12	(−.28, .03)		−.08	(−.24, .08)		−.14	(−.28, .01)		−.06	(−.21, .09)	
School functioning	Barely	−.06	(−.19, .06)	.003	−.04	(−.17, .10)	.54	−.01	(−.15, .12)	.24	−.01	(−.14, .11)	.41
	Definite	−.27	(−.45, −.10)		−.04	(−.19, .11)		−.11	(−.27, .06)		−.07	(−.21, .08)	
Boys													
Psychosocial summary	Barely	−.05	(−.20, .11)	.02	−.13	(−.30, .05)	.07	−.21	(−.35, −.07)	<.001	−.18	(−.33, −.04)	.04
	Definite	−.33	(−.56, −.09)		−.16	(−.38, .07)		−.41	(−.66, −.16)		−.10	(−.31, .11)	
Emotional functioning	Barely	−.03	(−.18, .12)	.01	−.14	(−.30, .01)	.01	−.31	(−.46, −.16)	<.001	−.21	(−.34, −.07)	<.001
	Definite	−.37	(−.60, −.14)		−.24	(−.47, −.01)		−.35	(−.59, −.12)		−.31	(−.54, −.08)	
Social functioning	Barely	−.05	(−.20, .10)	.06	−.11	(−.28, .06)	.15	−.14	(−.28, .00)	.001	−.15	(−.30, .00)	.16
	Definite	−.22	(−.46, .02)		−.11	(−.33, .11)		−.30	(−.52, −.09)		−.04	(−.26, .18)	
School functioning	Barely	−.02	(−.17, .14)	.22	−.06	(−.23, .10)	.41	−.09	(−.22, .05)	.005	−.10	(−.24, .04)	.86
	Definite	−.17	(−.40, .06)		−.06	(−.28, .16)		−.28	(−.51, −.05)		.08	(−.11, .26)	
Gender interaction													
Psychosocial summary	p[c]	.61			.89			.08			.64		
Emotional functioning	p	.34			.60			.07			.13		
Social functioning	p	.56			.83			.27			.87		
School functioning	p	.41			.83			.26			.58		

CI = confidence interval.
[a] Regression coefficient reflecting difference in z-score adjusted for age, ethnicity, socioeconomic status, and body mass index, in each case compared with no indication of puberty onset as the reference category.
[b] Test for trend by indication of puberty onset.
[c] Test for interaction between gender and trend by indication of puberty onset.

peer influences, could plausibly influence this process for girls and boys [28,39].

A key strength of this population-based study is that we collected the data prospectively with neither reference to puberty nor the potential for recall bias. Although the study findings were for a large and representative Australian population-based cohort, the analytical sample included slightly more socioeconomically advantaged children because of the lower availability of study measures for more disadvantaged children. Because it is likely that both rates of early puberty and mental health problems are higher among more disadvantaged children, this may have led to some understatement of true population effects based on the present research findings.

The study was limited by relying on parental report for the key variables; however, we included objective measurement instruments to standardize parental report as far as possible. We assessed puberty onset via parents' observation of their child's external signs of puberty, which may limit accuracy compared with direct physician ratings of children's pubertal status by Tanner staging [40]. We included a graded categorization of "no," "barely," or "definite" onset of puberty at age 8–9 years to allow for uncertainty in whether puberty had onset. At the later wave of the study, when the children were aged 10–11 years, we again included a more detailed pubertal index as a parent report measure. This was based on the indicators used by Petersen et al [31]: growth spurt, body hair and skin changes (boys and girls); deepening voice and facial hair (boys); and breast growth and menstruation (girls), from which a continuous measure indicating level of progression through puberty can be derived. Further analysis included in Supplementary Table 1 (which can be found online at the URL located at the end of this article) shows that the categories used to infer whether puberty had onset at age 8–9 years are predictive of this later detailed pubertal index, which supports the predictive validity of the categories used.

We measured childhood mental health indicators (behavior difficulties and psychosocial adjustment) by widely used and validated but brief parent report screening instruments [32,33]. Greater precision in determining children's clinical mental health diagnoses could be obtained via clinical interviews, but this was not feasible within the LSAC research design as a large-scale omnibus cohort study. We note also the modest level of internal consistency of items within each subscale of the screening instruments, which suggests that these reflect somewhat mixed constructs of adjustment or behavior (for example, difficulties with peers), rather than specific psychological traits. At age 10–11 years, we also asked children to describe their own behavior using the child-reported Strengths and Difficulties Questionnaire. Repeating the analysis of behavior difficulties using the child-reported measures gave results congruent with those based on the parental report (Supplementary Table 2, which can be found online).

The implication of these findings for continued research into the relationship between puberty and children's mental health is that, at least in part, the association between early-onset puberty and poor mental health appears to result from processes under way well before the onset of puberty. Understanding the developmental processes leading to early puberty may also offer insights into biological processes underpinning the early onset of emotional and social maladjustment. The analysis of longitudinal studies from pregnancy throughout childhood may unravel these questions further, particularly if these studies capture and quantify the timing of pubertal hormonal and physiologic changes. A future potential opportunity in LSAC will include investigation of the

birth cohort, which began in infancy and has richer information regarding the early development and environment preceding that which could be examined in this study. Furthermore, longer-term follow-up of children will allow us to address the potentially protective effects of later puberty and whether such effects persist into later adolescence and young adulthood.

This population-based study provides new evidence of pre-existing and persistent early childhood differences in mental health-related indicators among children who experience early puberty. These differences are apparent from the preschool years and continue into early adolescence. These findings are consistent with the idea that early puberty may be part of an accelerated trajectory of transition to adult development that begins early in life, and which includes heightened risks for childhood behavior and social adjustment problems.

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Supplementary data

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